



## Space Weather Workshop

The Meeting of Science, Research, Applications, Operations, and Users  
26-29 April, 2016, Broomfield, Colorado



# PSTEP

## Project for Solar-Terrestrial Environment Prediction

Kanya Kusano

Institute for Space-Earth Environmental Research  
Nagoya University



# Outline

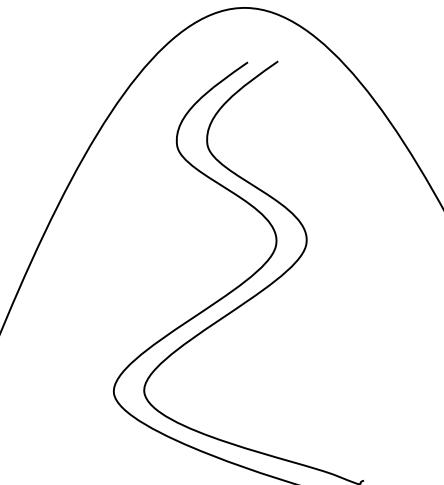
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- What is PSTEP
  - Motivation, Objectives & Organization
  - Strategies and Roadmap
- Research Topics
  - Flare prediction
  - CME prediction
  - Prediction of plasma bubble
  - Prediction of long-term variability
- International collaboration
- Summary

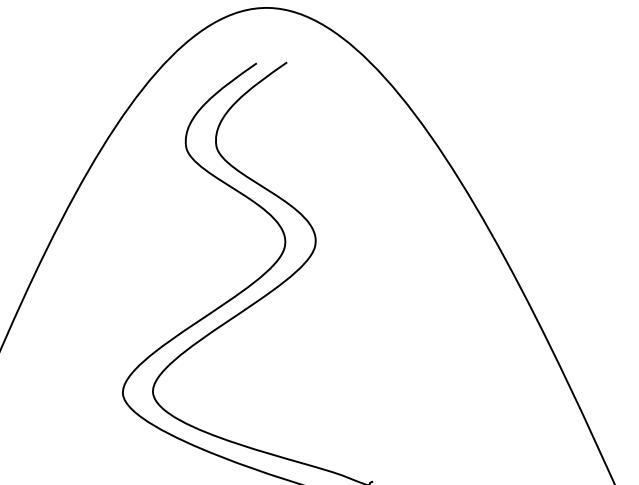
# Motivation of PSTEP

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“understanding”



“predicting”

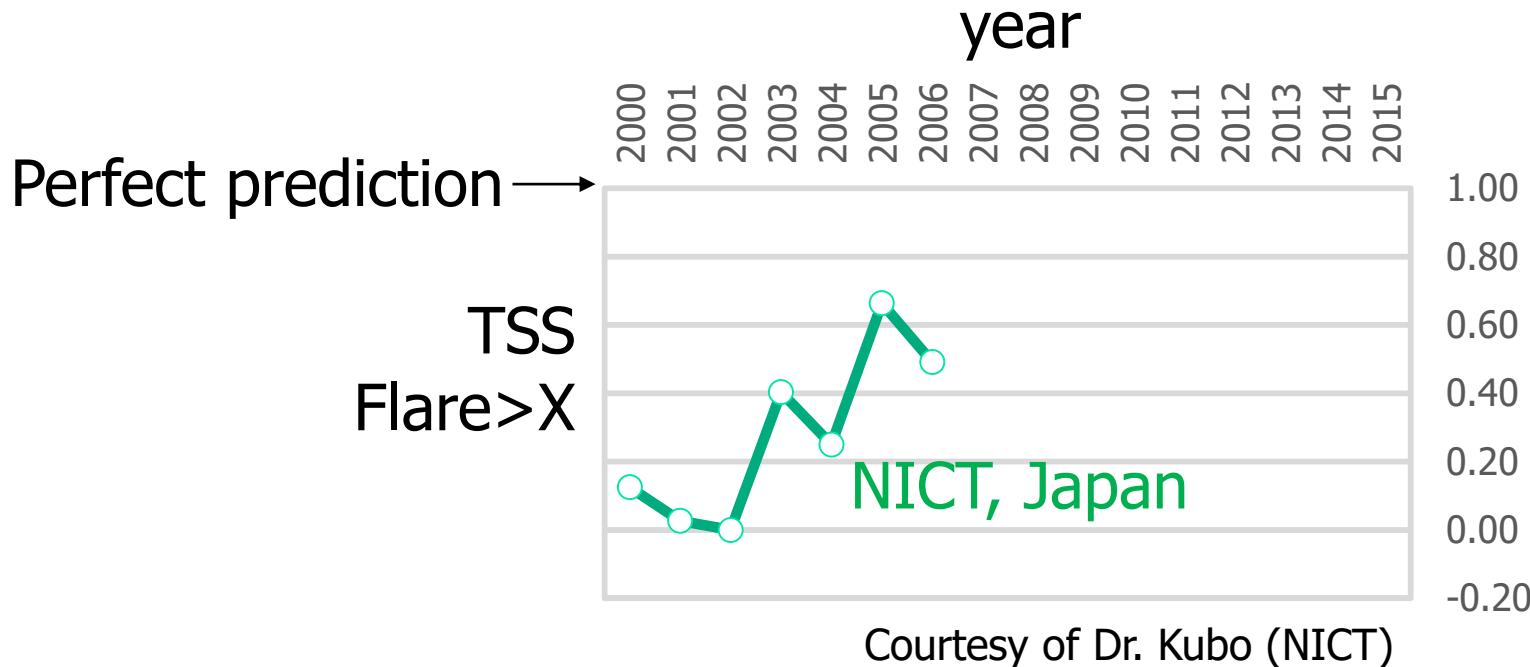


Valley of  
death

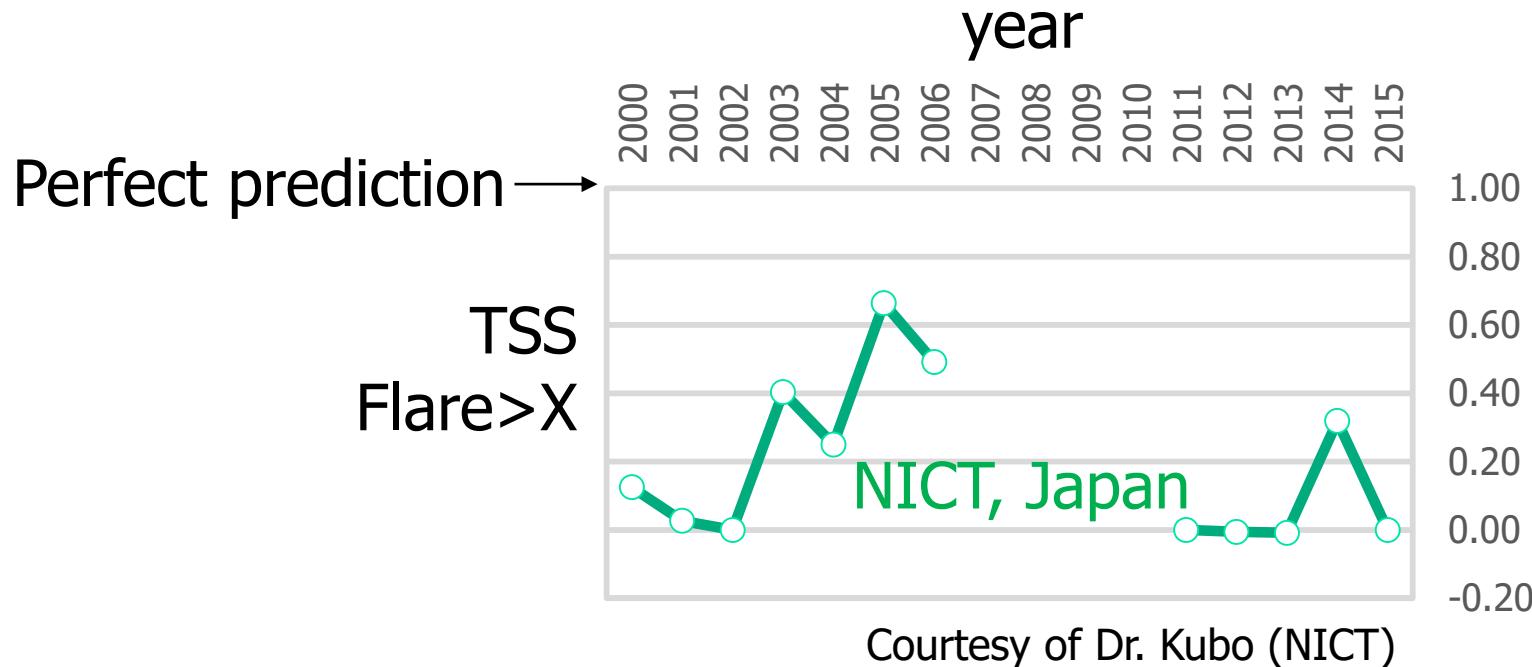
science  
research

forecast  
operation

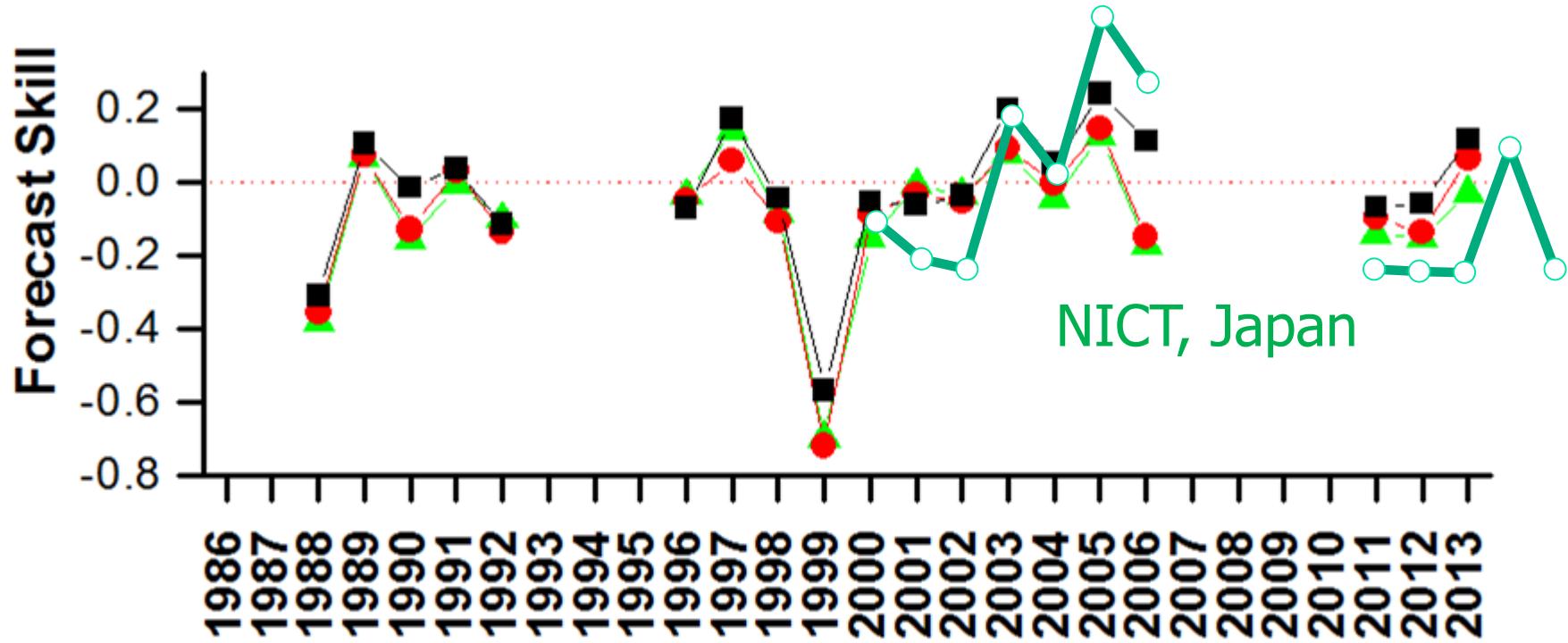
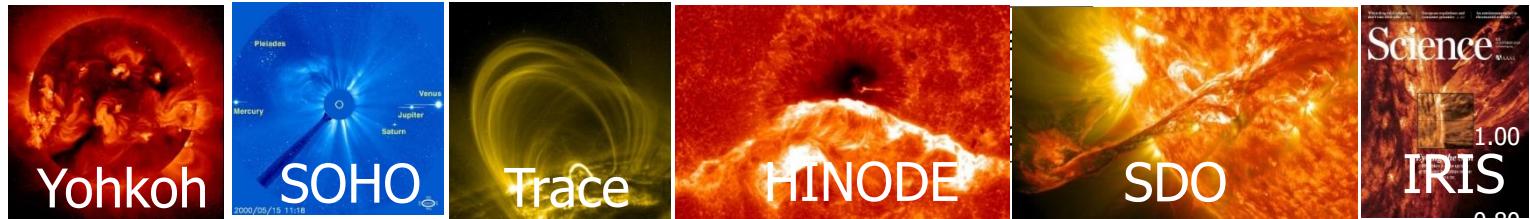
# History of Flare Prediction Skill



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# History of Flare Prediction Skill



2014, NOAA Space Weather Prediction Center, Boulder, CO, USA

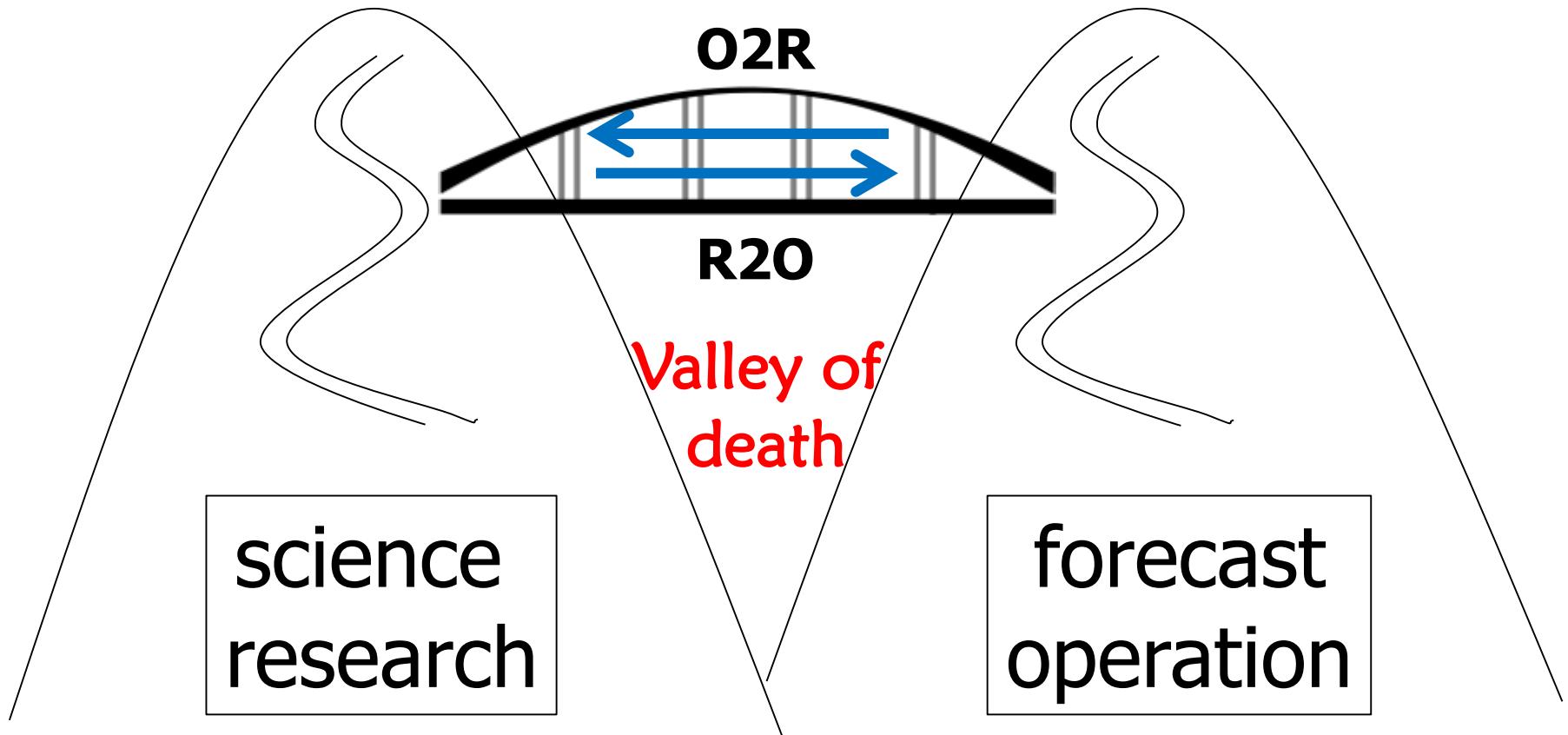
2016/4/29

<http://www.swpc.noaa.gov/content/solar-activity-forecast-verification>

# Research & Operation

“understanding”

“predicting”



Physics-based Models

## 太陽地球圈環境予測



synergistic  
development

【Objective 1】

To answer fundamental  
questions of solar-terrestrial  
environment:

- The onset mechanism of solar flares
- The mechanism of radiation belt  
dynamics
- The physical process whereby the sun  
affects climate

【Objective 2】

To build the base for next-  
generation space weather  
forecast system

- Useful prediction for each industrial  
activities
- Physics-based assessment of severe  
space weather disaster

**Physics-based Prediction**

+

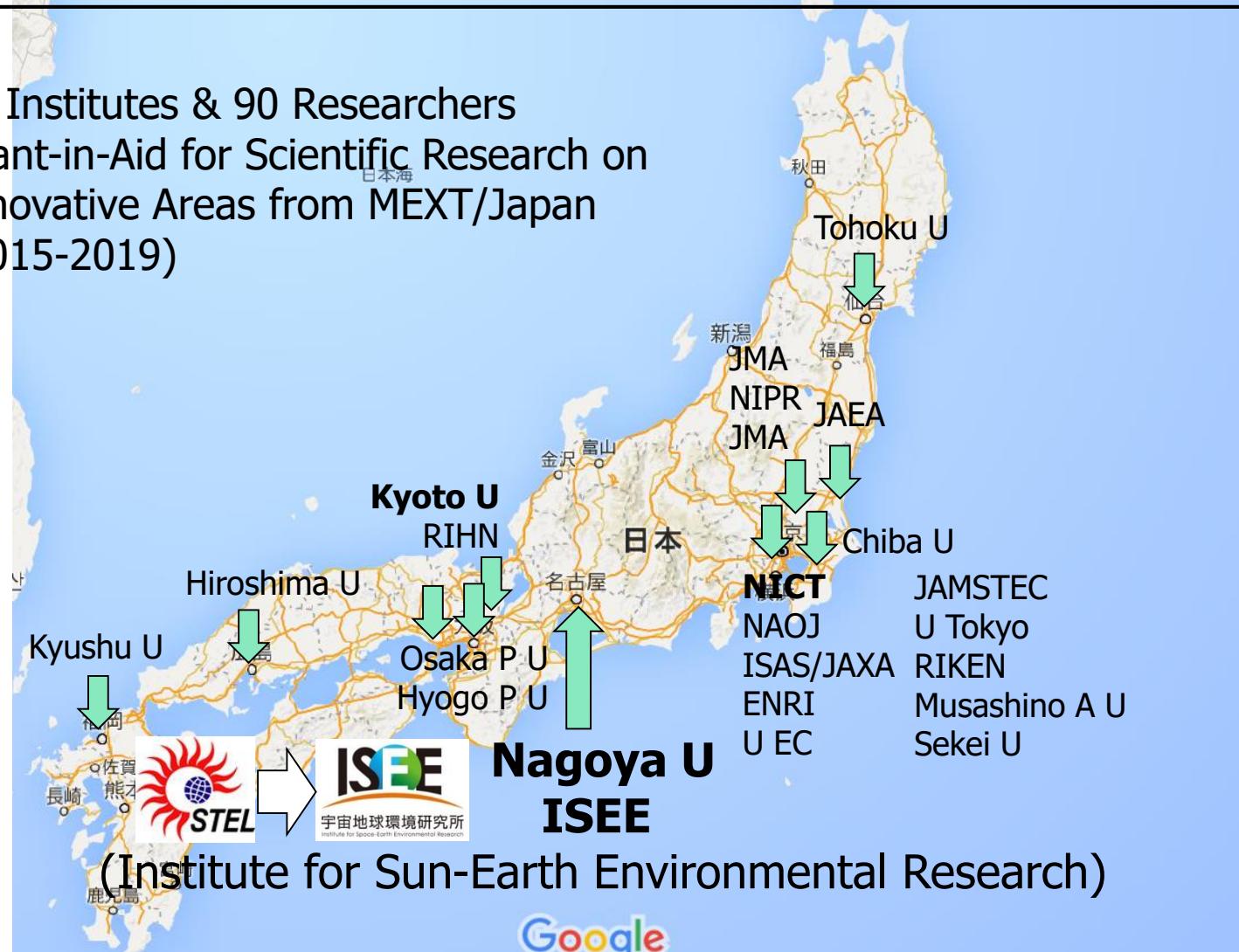
**Network Observation & HPC**



# PSTEP Network

## Project for Solar-Terrestrial Environment Prediction

- 20 Institutes & 90 Researchers
- Grant-in-Aid for Scientific Research on Innovative Areas from MEXT/Japan (2015-2019)



# Organization of PSTEP



International partners

Steering Committee  
Kusano (Nagoya U.)



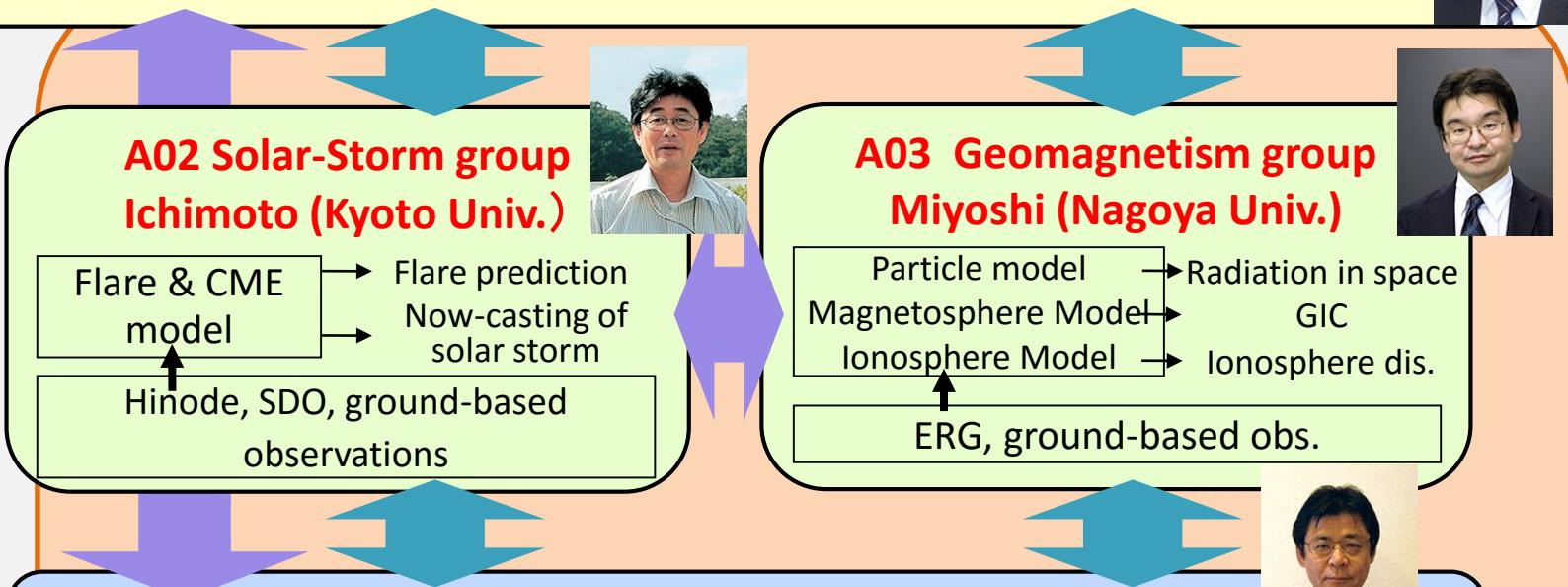
Partners in Industries

A01 Space Weather Forecast Operation Group Ishii (NICT)

① Forecast systems to meet the needs of society, Assessment of severe space weather



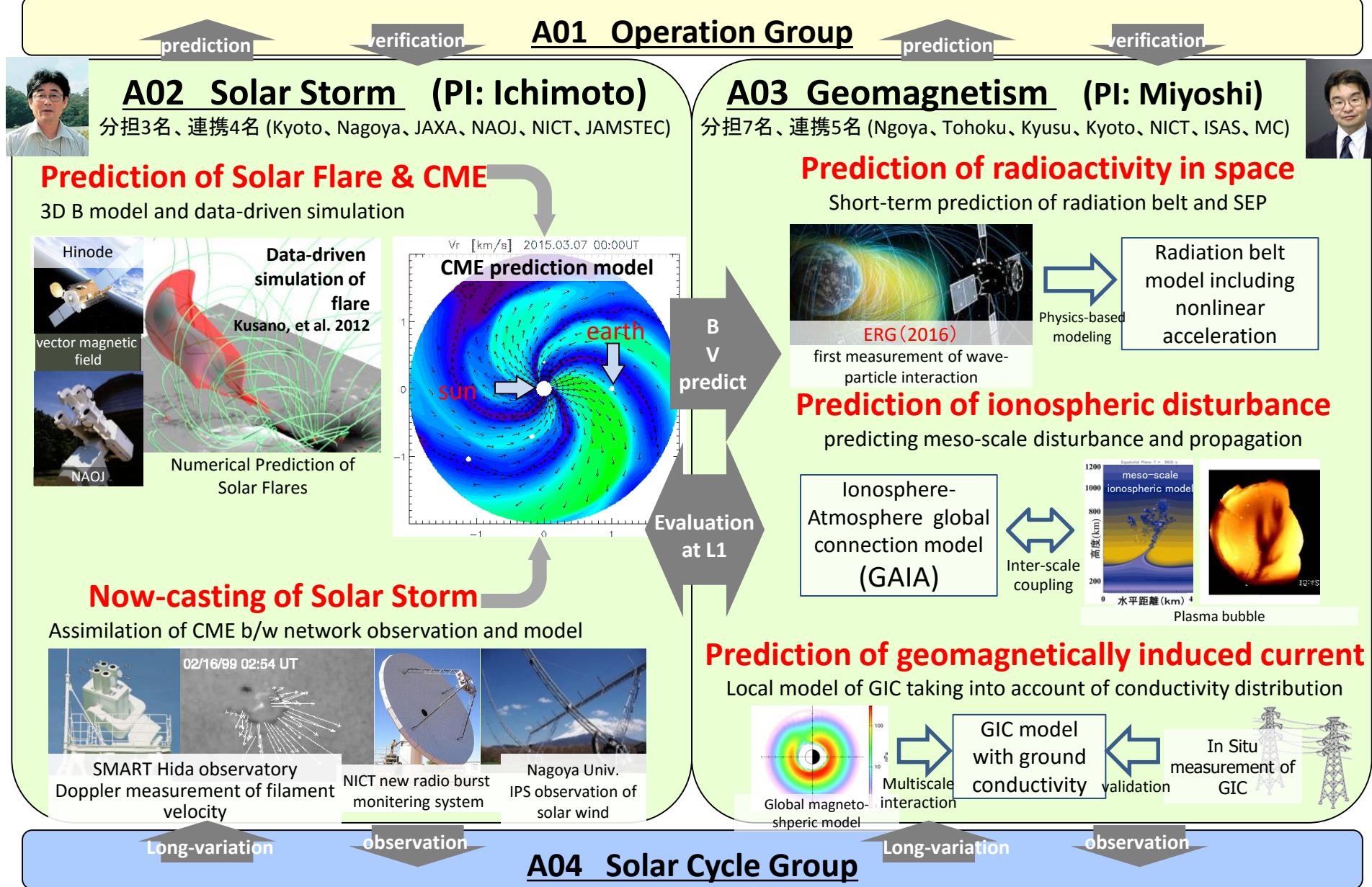
② Short-term  
(space  
weather)



③ Long-term  
(space  
climate)

Research Units (proposal-based)

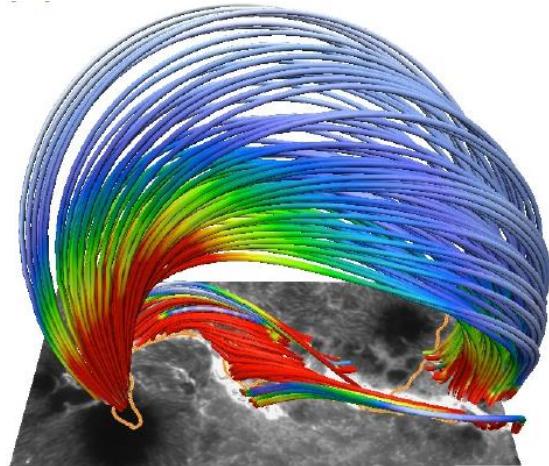
# ② Short-term prediction (Space Weather)



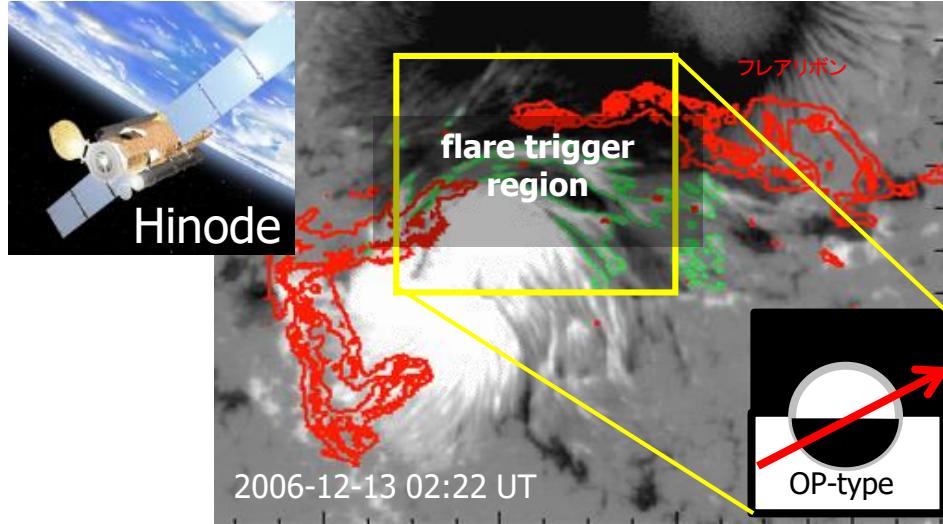
# Flare Prediction

To predict the onset of flares based on the stability analysis of 3D realistic magnetic field model.

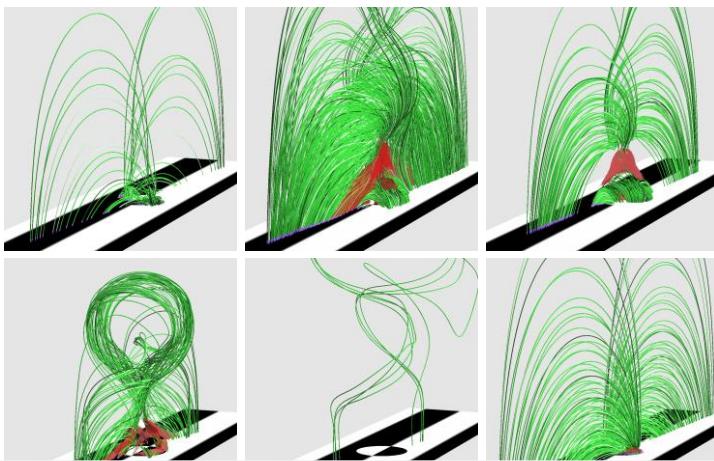
- Kusano+2012, Bamba+2013, Inoue+2016



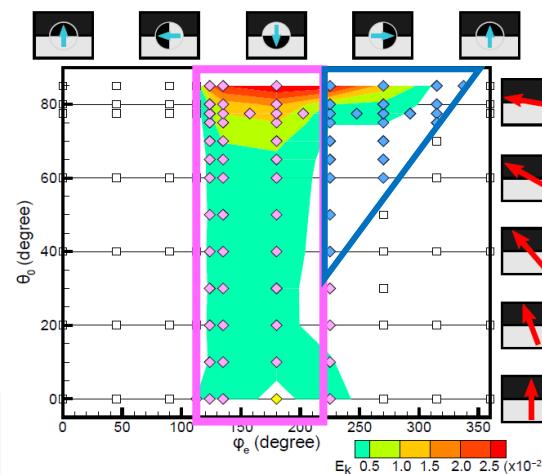
NLFF model



Vector magnetic field analyzer for flare trigger



Ensemble simulator for flare trigger

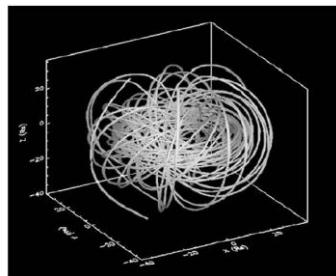
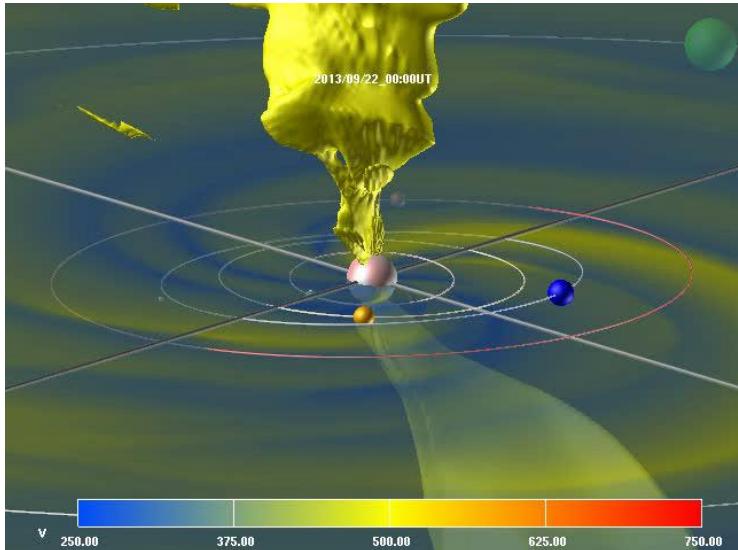


Distribution of possible flare energy on the parameter space of trigger field structure

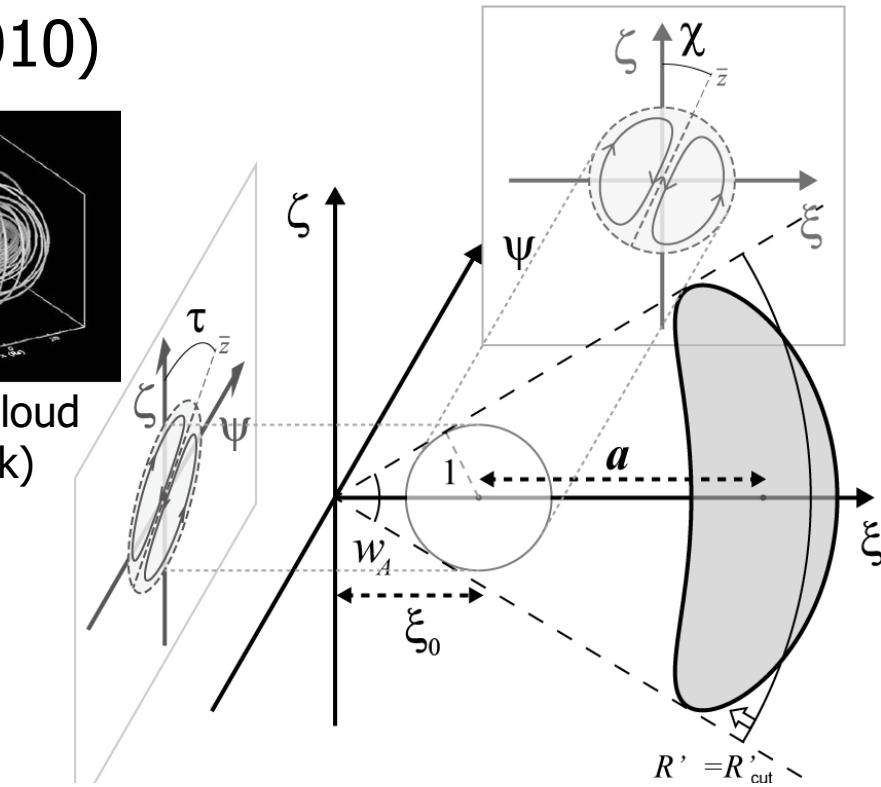
# CME prediction

To predict the magnetic polarity  $B_z$  at  $r=1\text{AU}$  using the vector magnetogram and 3D MHD simulation.

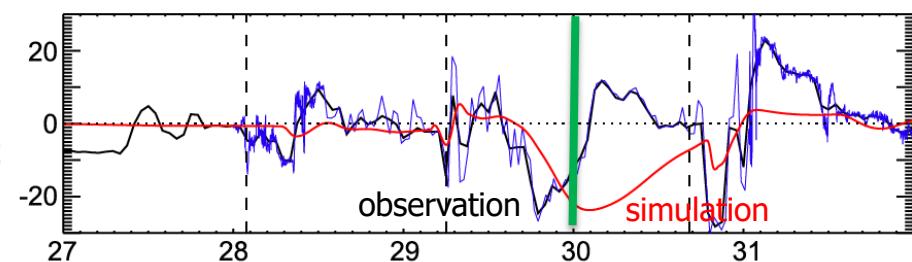
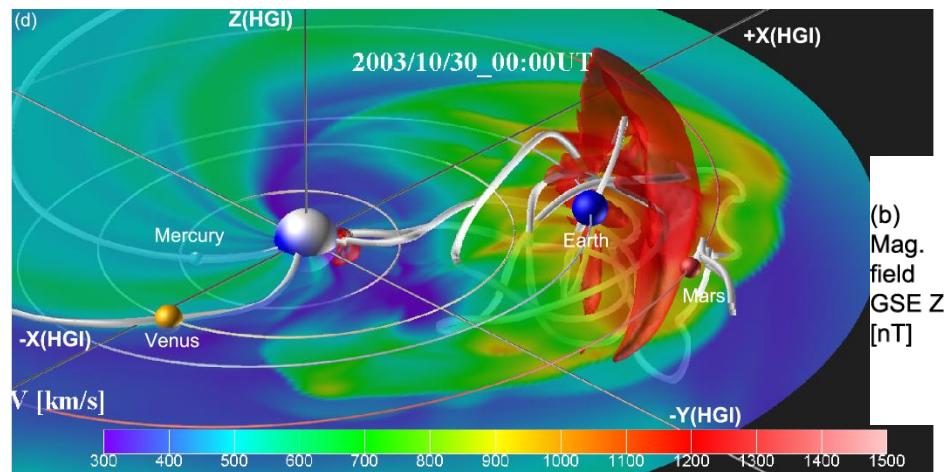
## SUSANOO (Shiota, et al. 2010)



magnetic cloud  
(spheromak)



Shiota & Kataoka 2016

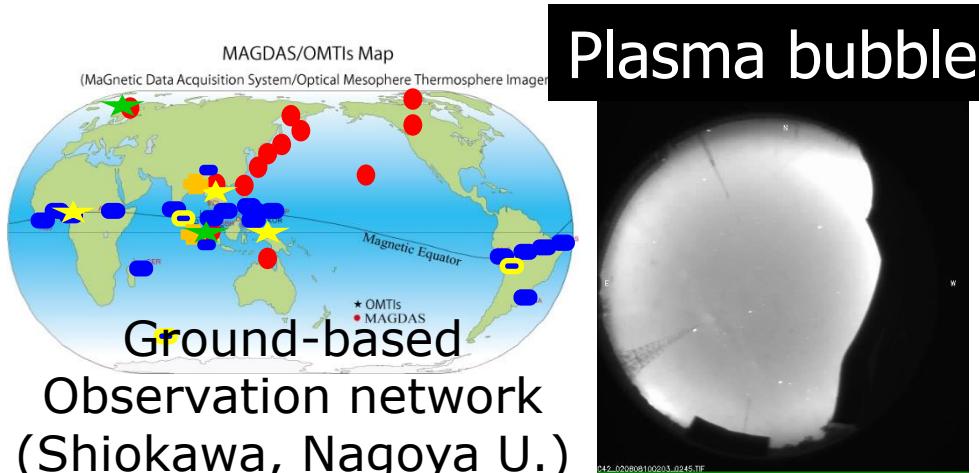


# Magneto-Ionosphere



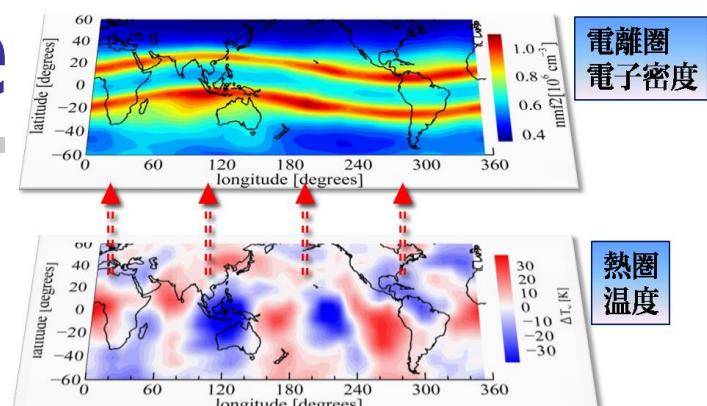
The physics based model of auroral breakup with substorms.

Ebihara and Tanaka (2015, JGR)

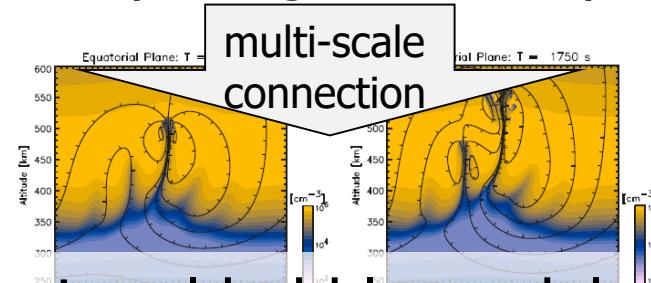


Plasma bubble

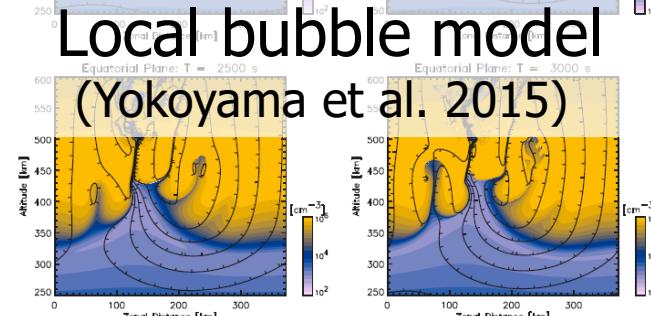
Ground-based  
Observation network  
(Shiokawa, Nagoya U.)



GAIA: Whole Atmosphere-Ionosphere Coupled Model  
(Shinagawa+ 2011)



Local bubble model  
(Yokoyama et al. 2015)



I contours by solid curves on magnetic equatorial planes at  $T = 0, 500, 1000, 1250, 1500, 1750, 2000, 2500$ , ours are drawn every 30 V. Tick marks on each contour indicate the direction of electric field vectors.

# ③ Long-term prediction (space climate)

## A01 Operation Group

prediction

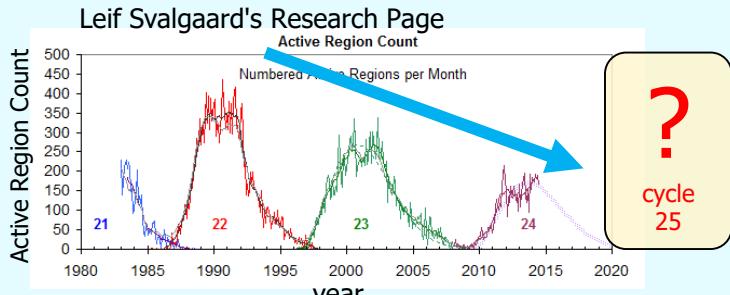
requirement

A02

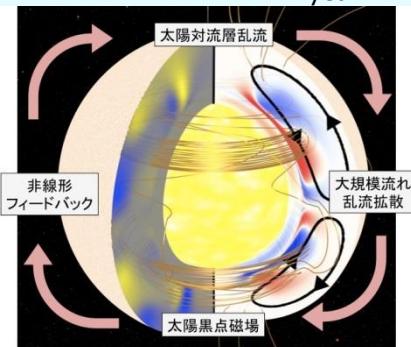
## A04班 PI Shigeo Yoden (Kyoto U)

Kyoto, Nagoya, Musashino-art, Seikei, Hyogo-pref, MC, NAOJ, NICT)

### Prediction of Cycle 25

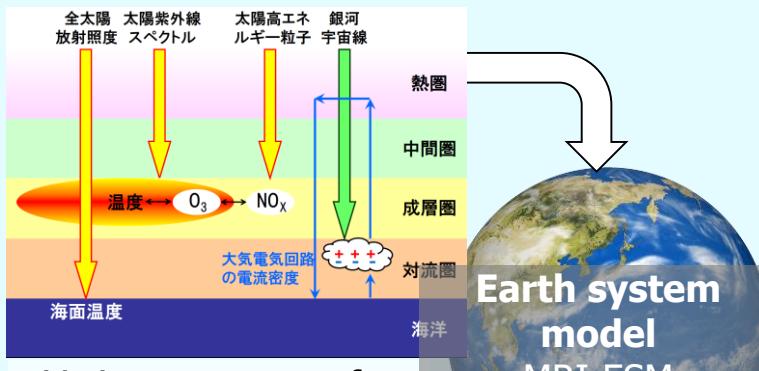


3D MHD model  
+  
flux transport  
dynamo model



3D dynamo model  
Using K-comp

### Mechanism of solar influence to climate



Earth system model  
MRI-ESM

IPCC気候モデル相互  
比較CMIP6に参加

### Evaluation of probability of Grand minimum and little ice age

→ 長期的な太陽地球圏環境変動を予測するための技術開発

Solar Storm

data

prediction

A03

variability

Geo-magnetism

data

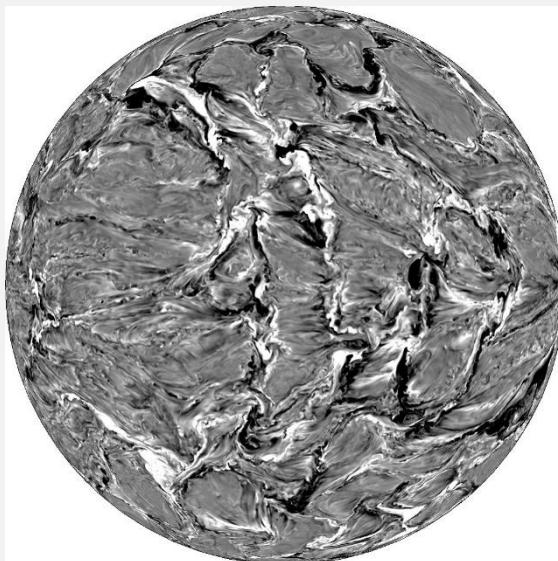
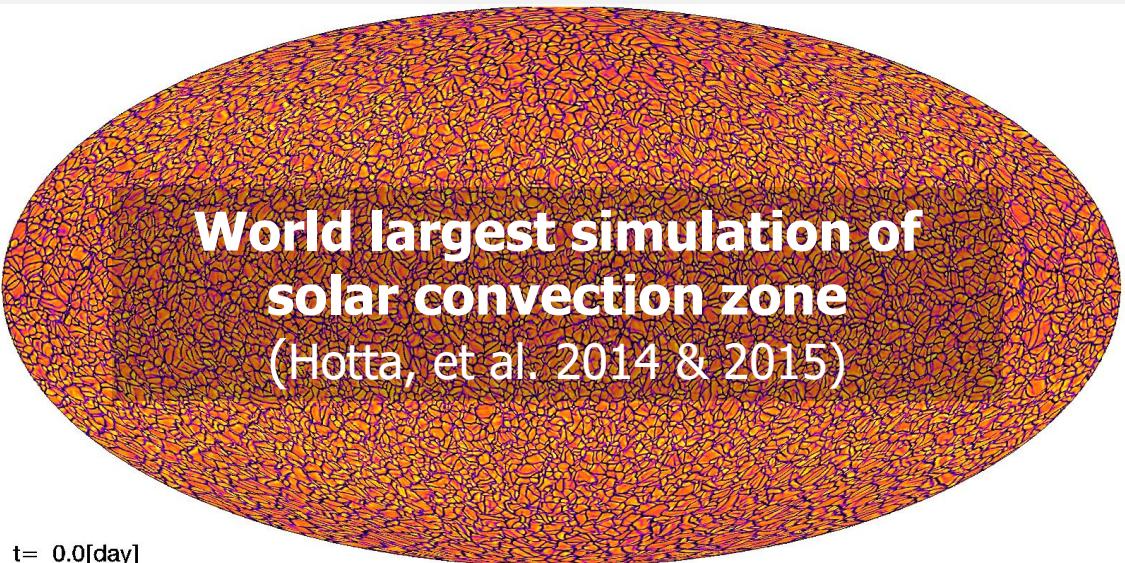
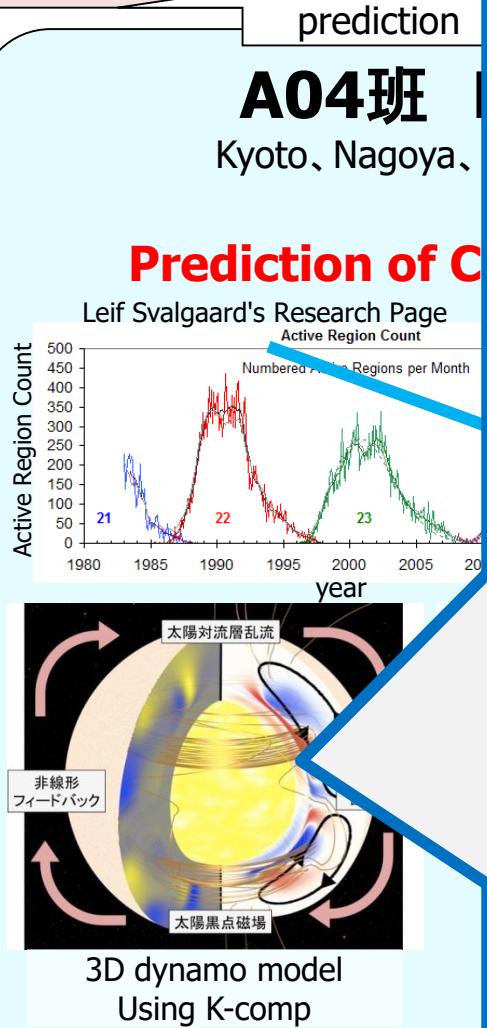
# ③ Long-term prediction (space climate)

A02

data

Solar Storm

prediction



World largest solar dynamo simulation  
(Hotta et al. 2016 Science)



K-computer

# ③ Long-term prediction (space climate)

## A01 Operation Group

prediction

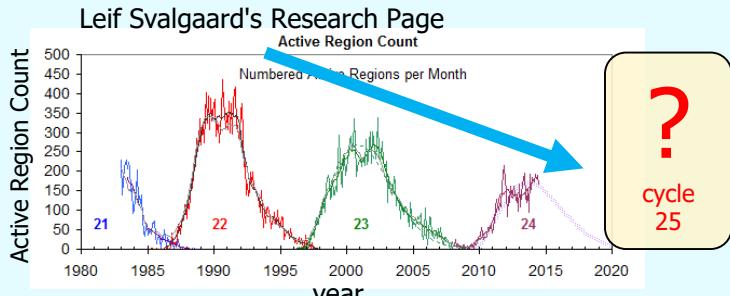
requirement

A02

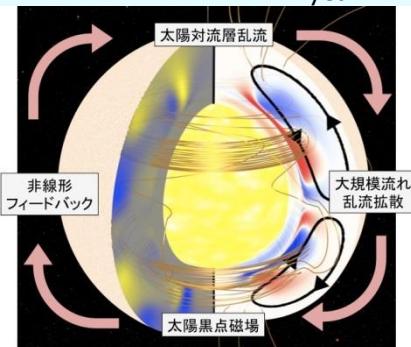
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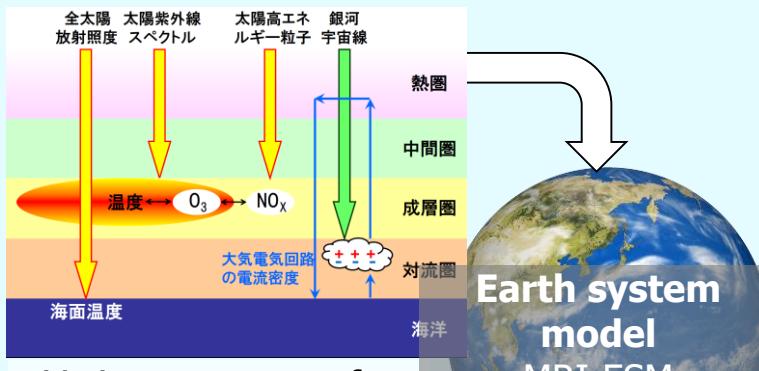


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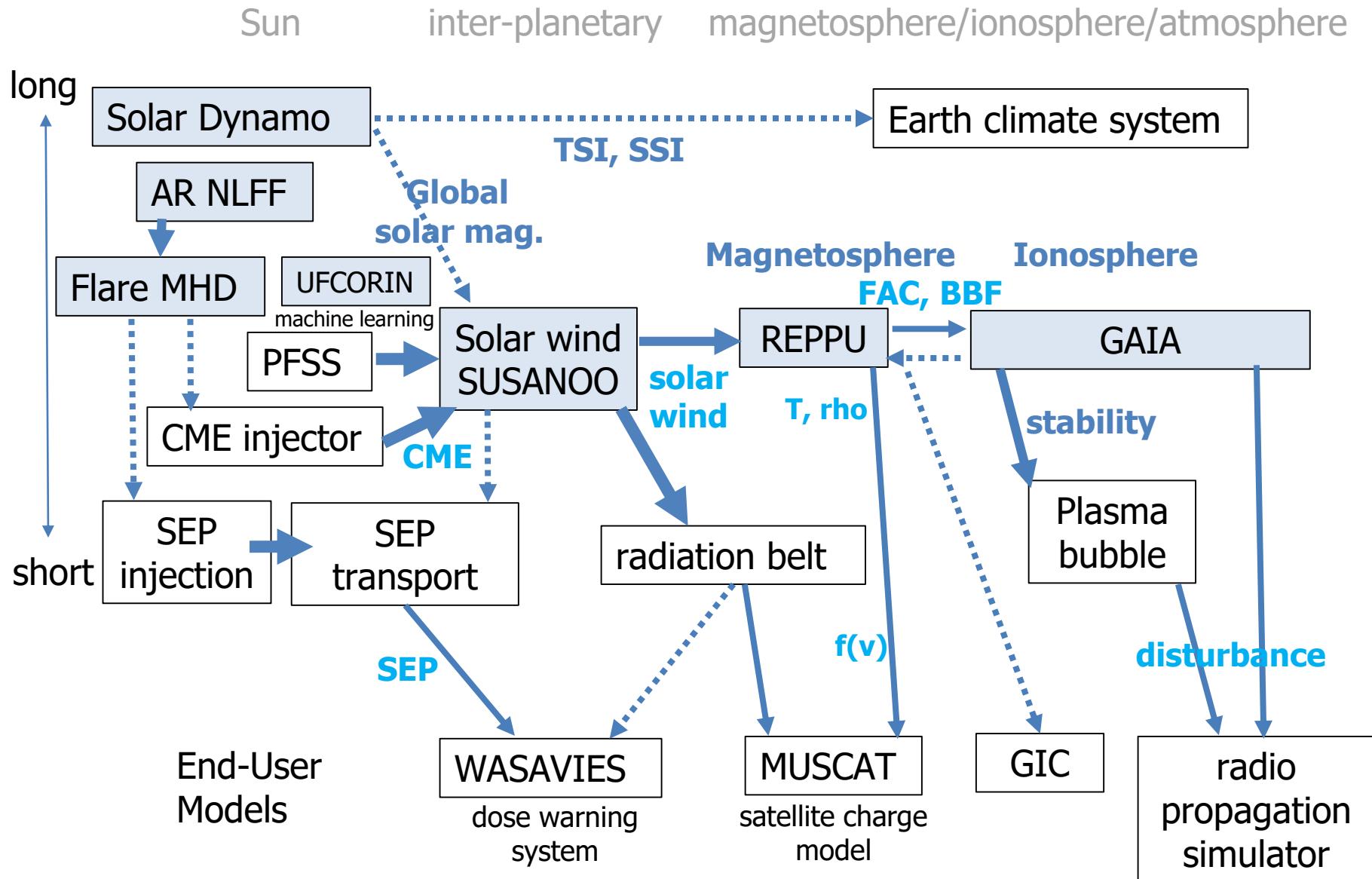
A03

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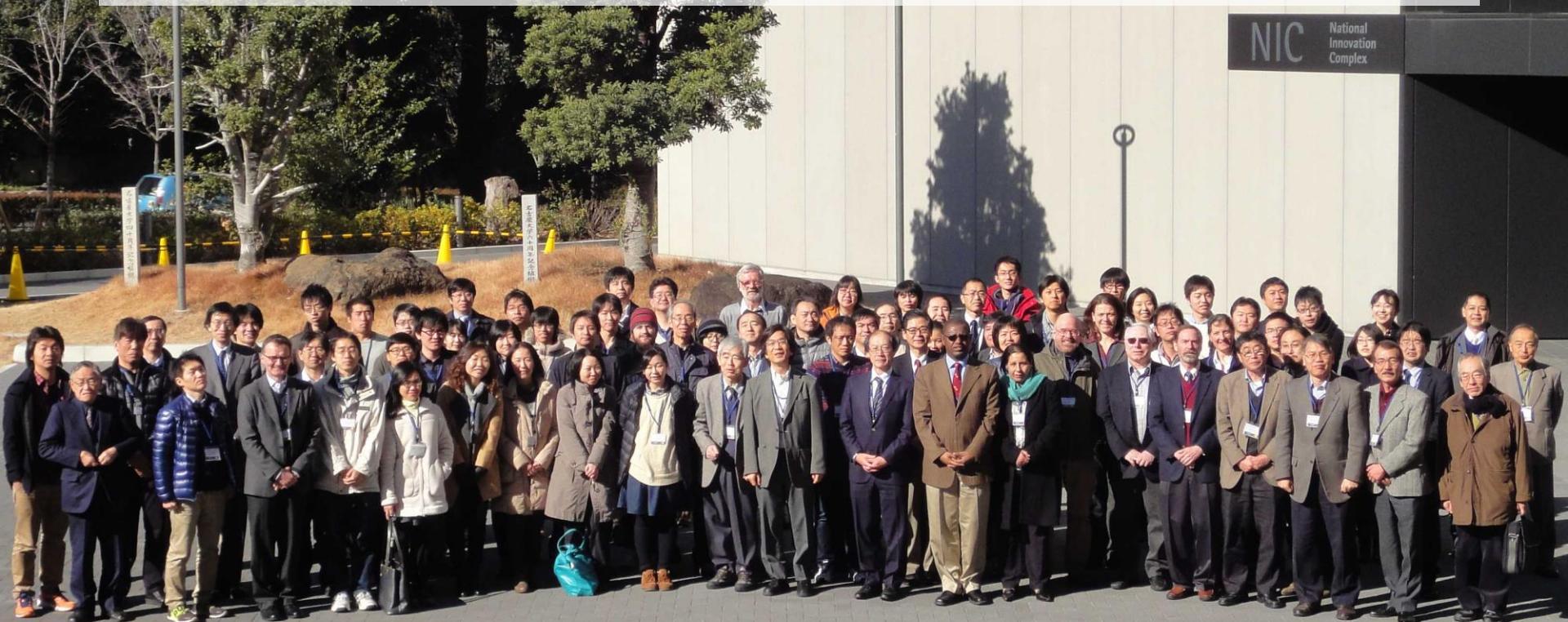
data

# System map of PSTEP models



# International collaborations

International Symposium PSTEP-1  
Jan 13-14, 2016  
Nagoya University, Japan



# International collaborations

## ■ Joint Meeting &Symposium

- PSTEP-1 Symposium on Jan 2016 at Nagoya
- AGU-JpGU joint session of Space Weather & Space Climate May 2016 at Makuhari near Tokyo
  - Invited speakers: Tom Berger, Steven Clarke, Michael Hesse, Jon Linker, Alphonse Sterling, Antti Pulkkinen, Yusuke Ebihara,...

Japan Geoscience Union  
May 22nd- 26th  
Makuhari Messe MEETING2016

JpGU and AGU to Collaborate in JpGU Annual Meetings in 2016 and 2017



## ■ Joint research

- Benchmark activity
  - Modeling validation challenge, Prediction skill score
- Joint development
  - Model, Assimilation, Post-processing, Visualization



# PSTEP

Project for  
Solar-Terrestrial Environment Prediction

PSTEP is a new nation-wide project in Japan for space weather & space climate study. PSTEP aims to synergistically improve both our scientific understanding and predictive capability. The international joint action is important for PSTEP.

